CHAPTER 8. OTHER MARKING MATERIALS

INTRODUCTION

In addition to the conventional paints, thermoplastic, and preformed tapes used as pavement marking materials, a number of other materials are used less-widely. Also, recent years have seen the introduction of a number of experimental materials. These materials have grown out of a variety of problems with current materials that have unacceptably high costs to environmental concerns.

This chapter describes some of the alternative materials, and also introduces a few of the new materials that have been tried. Where available, evaluations of each material's effectiveness and economy are included.

USES

The uses of other marking materials are the same as those of conventional pavement marking materials. These materials may be more or less well-suited to a particular area, based on the delineation variables. For example, water-based paints are often not recommended for application during periods of high humidity. More of these concerns are discussed for each material.

TYPES

A wide variety of materials have been tried as pavement markings. Alternatives have been tried for many reasons, from environmental to the desire for year-round durability in a standard pavement marking. Not all these attempts have been successful. In this chapter, we will cover only those materials that have met with some success.

Latex Paint

One of the major concerns with traffic paint has been the environmental hazard created by its use. Volatile organic compounds (VOCs) are released into the atmosphere by the solvents in paints, and the pigments used are often lead based. There have been concerns that the lead from these pigments may end up in the water table after the markings have worn off the roadway.

These environmental concerns are discussed in more detail in chapter 4. These environmental problems are important, because traffic paint is by far the most widely used marking material. While thermoplastic materials do not cause the same types of environmental concerns as paints, they are significantly more expensive.

One widely publicized material, proposed as a solution to the environmental problems with paint, has been water-based, or latex paints. These materials are similar to conventional paints in theory of operation, but the hazardous materials have been removed.

The study discussed in chapter 4 investigated alternatives to conventional lead-based pigments. Currently, no definitive alternative has been established to lead-based pigments. None of the materials tested exhibited the excellent yellow color durability achieved by the paints using lead-chromate pigments.

Epoxy Paint

Two-component epoxy paints were developed in the early 1970s by the Minnesota DOT, in conjunction with the H.B. Fuller Company. Their objectives were to create a durable, sprayable material that would adhere to both bituminous asphalt and Portland cement concrete (PCC) pavements with good abrasion resistance. Major concerns about formulating the product involved acceptable cure times, bonding characteristics, and color retention.

Twenty years later, epoxy paints have become a major alternative among pavement marking techniques. Much research has gone into their development and testing. A variety of formulations are on the market now, their manufacturers vying to be at the forefront of the technology.

Polyester, Solids

The evaluation of polyester marking materials was initiated in 1975 by the Ohio DOT in cooperation with the Federal Highway Administration (FHWA). The project was designed to evaluate color, durability, and retroreflective performance of this type of material for a three-year period.

Polyester markings have not been used extensively nationwide. Experience with the material has been limited to the Mid-Western States. Michigan DOT is a principal user. It is recommended for asphalt roads having medium- to high-volume traffic. Highway agencies have not shown much enthusiasm for polyester material because of its slow drying time. In cooperation with a major paint manufacturer, Michigan DOT has developed a new material that drys to no track in 60 seconds. The fast-dry polyester material should find an increased usage throughout the nation.

Epoxy Thermoplastic

Epoxy thermoplastic (ETP) is a generic pavement marking material composed of epoxy resins, pigment, filler, and glass beads. This material differs from most epoxies in that no hardener is used.

Two formulations have been field-tested extensively. These formulations vary in the ratio of the two epoxy resins-one a solid, the other a liquid-used in the material. A l-to-l solid-to-liquid ratio yields a flexible material designed for localities experiencing moderate-to-severe winter conditions. A 3-to-2 solid-to-liquid ratio was designed for regions with hot, dry summer weather. A harder material results, which is less susceptible to summer road film pickup.

Actual field testing showed that both formulations perform about equally well under severe winter conditions. However, because of its ability to resist road film pickup, the 3-to-2 solid-to-liquid formula was selected for further study.

The specifics of the original formulation for white ETP is given in table 8.[75] The total weight shown in the table represents a volume of 12.8 gallons (48.5 liters). This will yield a weight per gallon of 13.1 pounds (5.9 kilograms per liter).

Since the original formulation was released, many FHWA-sponsored ETP demonstration projects have been attempted. However, ETP has not experienced large-scale use because of its disappointing cost-service life ratio. According to one of the material's producers, Pave-Mark, (Atlanta, GA) the price of one of the epoxy resins making up ETP nearly doubled shortly after the material's inception. This price increase forced the material's selling price beyond the point where its use could possibly be cost-effective.

The majority of the ETP demonstration projects took place from 1980 to 1986. In terms of the material's cost-effectiveness,

Table 8. White ETP composition

Component	Weight	
	Pounds	**Kilograms**
Ciba-Geigy 7097 Araldite epoxy resin or equivalent	60	27
Ciba-Geigy 6010 Araldite epoxy resin or equivalent	40	18
DuPont R900 titanium dioxide or equivalent	20	9
Georgia Marble Cal White Pigment Grade Calcium Carbonate	20	9
Cataphote Division (Ferro Corp.) Premixed Gradation reflective glass beads or equivalent	28	13
TOTAL	168	76

the high-priced materials in its formulation, the results of these tests were not promising. Currently, there are no major users of this marking material. However, Pave-Mark announced another change in the price of the epoxy resins used in the past to manufacture the material and released a new ETP product in 1992.

Methyl Methacrylate

Methyl methacrylate has been introduced and publicized as a nonhazardous, field-reacted, two-component, cold-curing material. Vendors recommend that the material be applied in a 4-to-1 resin-to-catalyst mixing ratio. It is a 100 percent solids formulation that is mixed in a static mixer just before application. The material can be applied by either a spray or extrusion process. The mixing reaction at the time of application is exothermic. As the material cools, it bonds to the pavement.

Marking Powder

One new material has been promoted by vendors in the marking industry. It consists of a form of powder that is cornbusted as it is deposited on the pavement. The heat and phase change associated with the high heat of application cause the material to bond to the substrate. This material is easy to handle and apply, but obviously requires special installation equipment. The material is also claimed to be economical at about $0.08 per foot ($0.24 per meter) of marking, assuming a marking thickness of 10 mil (0.25 millimeters). It is also claimed that the material has nearly instantaneous no-track times. The powder material is claimed to be hereby as durable as the most durable traffic paints. Subjective evaluations of performance, cost-effectiveness, and durability are not yet available.

Other Materials

Much of the formal research into other marking materials has been performed in New York. One study by the New York State Department of Transportation investigated a variety of materials for pavement markings.[76] The study was part of New York's commitment to providing a roadway delineation system with year-round durability. The NYSDOT was attempting to find a marking material with a 12-month service life, at a price similar to that of conventional traffic paint. A coal-tar and polysulfide epoxy formulation, among other unique ideas, was attempted. To date, none of these new materials has exhibited a favorable cost-service life ratio as compared with conventional traffic paint.

PERFORMANCE

Performance is a very important factor for other marking materials. Since so many of the materials discussed in this chapter require specialized installation equipment, they must have good cost-to-service life ratios, or highway agencies will not be interested in experimenting with them.

Though few of these materials have undergone appreciable formal research into their performance, some characteristics relating to the performance of each type of material are discussed in the following sections.

Latex Paint

To date, the results of research concerning latex paints have been mixed. One NYSDOT study examined water-based synthetic resin emulsions that solve some of the environmental problems with traffic paint.[60] The study found that use of water-based paint looks promising. It cited latex paints as having the following appealing characteristics: easy cleanup and recycling of containers, minimal environmental impact, and decreased safety hazards to workers. The study of its durability, drying times, and costs were promising, but successful large-scale field experience was limited at the time of the report.

A study at the Pennsylvania DOT (Northeastern Association of State Highway and Transportation Officials [NASHTO] Regional test facility) resulted in similarly promising results.[25] Table 9 is a comparison of service lives for latex paints versus conventional paints and other materials. These are given as estimated median useful lifetimes in days. As the table shows, the water-based formulations demonstrated service lives considerably longer than those of other formulations of traffic paint in the test. However, the usefulness of these paints has been questioned in actual applications.

A survey of highway agency engineers reported in a recent issue of *Better Roads* magazine cited several problems with installation and performance of latex paints.[54] The engineers complained that the material does not dry as quickly as it is supposed to, especially in foggy or humid weather. One highway agency representative is quoted as saying that the water-based paint came off the road in sheets and washed away during the first rain after installation.

Further research is needed to establish what factors definitely influence the performance of water-based paint, and when it can be used in a cost-effective manner.

Epoxy Paint

In the search for a viable low-cost, year-round delineation material, NYSDOT conducted durability testing of epoxy paints.[61] It was found to be a durable material in certain tests. In fact, their test of epoxy paint on low-volume roadways or rural expressways managed service lives of five years or more.

Because of these promising results, NYSDOT conducted more extensive tests,

Table 9. Estimated service life by class (median lifetimes in days)

	Arizona		Florida		Pennsylvania	
	OGAFC	PCC	DGAFC	OGAFC	DGAFC	PCC
Alkyd--White	163	>900	>900	101	341	390
Alkyd--Yellow	293	>900	>900	173	258	284
Chlor Rubber--White	478	>900	>900	255	444	470
Chlor Rubber--Yellow	159	>900	368	83	389	470
Water-base--White	>703	>900	>900	>900	505	823
Water-base--Yellow	>765	>900	>900	>900	474	684
Solv. Borne Epoxy--White	755	>900	>900	436	>1100	>1100
Solv. Borne Epoxy-- Yellow	>900	>900	>900	400	>1100	>1100
Urethane--White	883	>900	>900	577	630	>1100
Urethane--Yellow	617	>900	>900	607	578	>1100
Thermoplastic--White	>900	>900	>900	824	>1100	413'
Thermoplastic--Yellow	>900	>900	>900	420	>1100	354'
Cold Plastic--White	>900	>900	>900	377	386	>1100
Cold Plastic--Yellow	>765	>900	>803	625	298	365
Foil Tape--White	>900	>900	>900	>900	N A	N A
Foil Tape--Yellow	>900	>900	>900	>836	N A	N A

NA - Not Available
OGAFC - Open-graded asphaltic concrete
* - Data may not be reliable due to snowplow damage
DGAFC - Dense-graded asphaltic concrete
PCC - Portland cement concrete

marking 3,500 miles (5,635 kilometers) of roadway with the epoxy paint material.(77) Most of these installations performed well, but a few showed little or no durability. In most cases the epoxy seemed less sensitive to application factors than did thermoplastic materials. These results suggest that the problem might lie with unknown environmental factors or improper marking practices. Because field experience with epoxy paint is so limited, it is difficult to tell what may have caused these early failures.

Polyester

Field observation of this product indicated that the material is generally performing well and should continue to be serviceable for several years. In some areas with heavy traffic volumes, the polyester markings were worn out after one year of service. In these areas, paint lasts only three months.

The project demonstrated that polyester markings are more opaque than paint applied under similar conditions and look better during the daytime than two coats of paint. Nighttime visibility of polyester markings also is superior to that of paint because of the increased number of beads used.

A more recent research project in Pennsylvania tested 11 different samples of polyester marking materials. The estimated service lives derived for the white and yellow markings can be seen in table 10. These can be compared with the values for the other classes of materials tested, shown in table 9.

Table 10. Durability of polyester marking materials

WHITE

Material Class	Material Number	Estimated service life in days on DGAFC	Estimated service life in days on PCC
Polyester	91		**1082**
Polyester	92	>1100	
Polyester	97	>1100	
Polyester	98		>1100
Polyester	99	>1100	
Polyester	100		>1100
Polyester	101		>1100
Average White		*>1100*	*>1096*
Median White		*>1100*	*>1100*

YELLOW

Material Class	Material Number	Estimated service life in days on DGAFC	Estimated service life in days on PCC
Polyester	93	447	
Polyester	94		1024
Polyester	95	769	
Polyester	96		722
Average Yellow		608	873
Median Yellow		608	873

Epoxy Thermoplastic

Despite the woeful cost-service life ratio for ETP reported in the previous section of this chapter, the recent pricing change in epoxy resins in the material's formulation has caused the Pave-Mark Corporation to re-enter the market with an ETP product.

Pave-Mark estimates the new material will last about six times as long as conventional alkyd traffic paints under similar traffic and climatic conditions, at a contracted cost about 4.5 to 5 times that of standard paints. If this ratio can be achieved, ETP's fast no-track times and ability to work equally well on nearly any surface may again make it an attractive alternative to conventional traffic paints.

Methyl Methacrylate

Vendors cite methyl methacrylate as a durable material that is a viable option for environmental concerns. They claim service lives of from 3 to 10 years at costs similar to those of epoxy. In addition, the material is designed to be resistant to oils, antifreeze, and other common chemicals found on the roadway. Actual experience has been limited.

Various formulations of methyl methacrylate were tested by the Pennsylvania study.[25] The service lives obtained for these materials are shown in table 11.

The other materials discussed have not shown significant merit, or experience is so limited that performance factors are not discussed here.

INSTALLATION, MAINTENANCE, AND REMOVAL

Installation, maintenance, and removal concerns for the marking materials discussed in this chapter are the same as for standard traffic paints. Factors, such as line protection, crew safety, application width and geometry, and warehousing and storing of material, are fairly standard for longitudinal marking applications. Some concerns, such as protection of the new marking, will depend more on each specific material's formulation (drying time) than on the class of materials to which it belongs. Some specific information related to each class of material is given in the following sections.

Latex Paint

Handling of latex paints is simpler than for standard paints since the water base in these paints is not toxic.

Latex paints are a particularly attractive option because they do not require special installation equipment. In addition, the equipment that is used is much easier to clean up because of the lack of environmental hazard from these paints. These factors do not generally apply to new, experimental materials.

Epoxy Paint

Epoxy compounds are supplied in both white and yellow and normally are applied at a thickness of about 15 mil (0.38 millimeter). It can be installed without coning depending on the amount of glass beads used. The slower curing, less expensive formulas are intended for edgelines. The curing time varies according to the temperature of the pavement. The higher the temperature, the faster the material cures. It can be applied, however, at temperatures as low as 35 degrees Fahrenheit (2 degrees Celsius). If free

Table 11. Service lives of methyl methacrylate marking materials

State of Test	Estimated Service Lives (Days)			
	Arizona		Florida	
Substrate Type	OGAFC	PCC	DGAFC	OGAFC
Average (White)	>900	>900	868	>900
Average (Yellow)	803		>900	
Median (White)	>900	>900	>900	>900
Median (Yellow)	835		>900	

surface water is removed first, epoxy can even be applied to wet pavements.

To obtain the best bond, the surface must be clean. Because this material is not affected by dampness, the surface may be cleaned by a hot-water 150 degrees Fahrenheit (66 degrees Celsius), high-pressure 2000 pounds per square inch 13,800 KPa spray. The spray gun can be located just ahead of the epoxy spray gun. Between the water spray and the epoxy spray, there should be an air nozzle to remove free water. Epoxy paint cannot be placed over markings made from other materials.

Equipment

Epoxy paints cannot be applied from standard stripers. In the initial attempts, the two-part epoxy could only be applied with Fuller's striper. Now, contractors that apply epoxy markings for DOTs normally have their own specially designed stripers for epoxy application, These stripers usually have a high-pressure water nozzle, followed by an air blast nozzle, and finally the epoxy and bead nozzles. The epoxy must be mixed immediately before being sprayed onto the pavement. This requires additional hardware for the separation of the epoxy components before application, and mixing nozzles ahead of the spray nozzles.

However, there are some methods for modifying standard stripers. A number of highway agencies and contractors customize their own stripers to meet the needs for epoxy application.

Polyester

Polyester marking material is applied at a thickness of 15 mil (0.38 millimeters) with a drop-on bead application rate of 20 pounds per gallon (34 kilograms per liter). The two-component polyester system (resin and catalyst) will dry to a no-track condition in less than 30 minutes, provided the pavement is dry and the temperature is at least 60 degrees Fahrenheit (13 degrees Celsius). Faster drying times are achieved at higher temperatures. Typical drying times range from 8 to 12 minutes at 75 degrees (24 degrees Celsius). Because the film-forming mechanism is not an evaporation process, it can be applied at temperatures as low as 0 degrees Fahrenheit (-18 degrees Celsius) with proportionately longer drying times. Michigan DOT has developed a fast-drying polyester material for use.

This product does not adequately bond to PCC and its indicated use is for asphaltic pavements. However, it can be applied, however, over existing markings.

When polyester markings are applied to new asphalt surfaces, the polyester flakes off with the surface aggregate particles due to the presence of free oils. This creates a marking that appears full of holes when closely examined. This "Swiss cheese" effect does not harm visibility when viewed from a normal distance. This effect usually occurs within two months of application. After this initial loss, no further deterioration occurs. Michigan DOT does not apply its fast-dry polyester on AC pavements less than one year old.

Safety of workers is of prime concern when handling and applying polyester marking material. While the resin is not much more difficult to handle than paint, the methyl ethyl ketone peroxide catalyst is a noxious chemical requiring careful handing. Gloves and safety goggles should be worn when handling the material and during the marking operation.

Equipment

Like all field-reacted materials, polyester markings require special equipment for installation. Truck-mounted equipment is recommended. Conventional marking trucks can be modified for about $4,500 to $6,000.[78] A speed of 8 to 10 miles per hour (13 to 16 kilometers per hour) can be maintained when applying longitudinal markings.

Epoxy Thermoplastic

ETP is applied by the hot spray process at a temperature of 425 to 450 degrees (217 to 232 degrees Celsius). A top dressing of drop-on beads is applied almost simultaneously with the spray gun operation. Under certain conditions, no-track times of 5 seconds have been measured in the field. These fast no-track times often require that drop-on glass beads be heated so that they can sink to the proper depth in the film.

Application thickness ranging from 15 to 25 mil (0.40 to 0.64 millimeters) have proved durable on both asphalt and concrete pavements. Primer is not required for this application,

While the optimum application pressure and temperature have not been determined, the ETP demonstration projects discussed earlier found that the material was very sensitive to these variables. If new formulations of the material prove to be cost-effective, research will be needed to establish more precisely the optimum values for these variables. It appears that, though the material is very sensitive, it also can give excellent results if the application variables are properly determined and closely controlled.

As an example, one early project even managed to successfully apply ETP in below-freezing weather by varying application characteristics. For an installation in Denver, Colorado, the application temperature of the material was elevated to 485 degrees Fahrenheit (251 degrees Celsius), and was applied to a surface at a temperature of 22 degrees Fahrenheit (-5 degrees Celsius). The air temperature was 31 degrees Fahrenheit (4 degrees Celsius). No problems were experienced with this application. After one year, the site showed excellent bead retention and no discernible wear. If this performance could be repeated reliably, the range of climatic conditions under which pavements can be marked could be significantly expanded.

Methyl Methacrylate

Methyl methacrylate shows promise for ease of application. A variety of temperatures can be tolerated, and the material can be sprayed at a 40-mil (1.0- millimeter) thickness or extruded at 90 mil (2.3 millimeters) for transverse applications. Methyl Methacrylate is claimed to bond well to PCC pavements.

Equipment

Methyl methacrylate is a field-reacted material that cannot be applied using standard stripers. However, companies that sell methyl methacrylate marking materials will often also vendor their own special equipment for application of the material. This is similar for marking powders. The equipment it requires is similar to that required for epoxy application but is specialized nonetheless. Though the initial cost for buying these types of special equipment may be high, equipment costs are usually negligible when they are amortized over the life of the marking.

OTHER CONSIDERATIONS

The major factor inhibiting the use of new types of pavement marking materials is inertia. State and local highway agencies often are reluctant to change from products that they have used for a long period of time unless they can be convinced that the change will save a considerable amount of money.

In addition, many of these new materials require special installation equipment for field testing. As a result of the high initial investment required, highway agencies have been sluggish in adopting materials that seem to be more cost-effective than their current materials, The following sections discuss some of the cost concerns with the marking materials discussed in this chapter, and also the ways in which some of the materials have shown promise for increased use in the future.

Cost Considerations

Determining the optimum marking material for a given application can be complicated, even if exact costs are known for all possible materials. Of more concern to highway agencies is the ratio of cost-to-service life, and it always is difficult to predict how long a marking might last on a particular roadway. In addition, disruption to traffic and worker safety must be considered. Markings with very short service lives are not acceptable, even if they are very inexpensive, because a major portion of their marking cycles is spent simply waiting to be marked over after they have deteriorated to an unacceptable visibility level.

Keeping in mind that the following is a very superficial treatment of a very complex subject, some of the major cost issues are covered in the following sections for each of the marking materials discussed in this chapter.

The Minnesota DOT reported that a typical lane mile of skip markings could be painted five and one half times for the cost of one application of epoxy paint.(78) If the epoxy is serviceable for two years on high-volume roadways that are normally painted three times a year, the higher cost would be justified. Moreover, the marking crew would be exposed to traffic once instead of five to seven times. It would also provide a traffic delineation system throughout the winter season, which is not possible with paint.

Polyester

It is apparent that polyester markings perform better on asphalt pavements than conventional or fast-drying paints and some plastic materials. The initial cost is higher than that for paint and lower than that for two-part epoxy. Experience at the NYSDOT puts the price at about $0.07 per linear foot (22 cents per linear meter) in 1984.(60) The Michigan DOT has been using polyester for urban materials in the Detroit area at a cost of 6.5 cents per linear foot (21 cents per linear meter).

It is obvious that if the service lives demonstrated in the Pennsylvania DOT study (shown in table 10) can be consistently repeated, polyester will be one of the most cost-effective materials available.

Epoxy Paint

A cost comparison of conventional paint, epoxy paint, and thermoplastic material is given in table 12. These costs are taken from a revision to the Kansas DOT marking policy executed in 1988.(79) The material cost for epoxy ranges between thermoplastic and paint at about 17 to 25 cents per linear foot (54 to 80 cents per linear meter).

Epoxy Thermoplastic

Pave-Mark estimated that the new formulation of ETP marketed in 1992 could be contract-installed for a price of around $0.18 cents per linear foot ($0.59 per linear meter). However, costs for retrofitting State marking equipment to use ETP would require a high initial investment in the new technology by highway agencies. However, if the funds are amortized over the life of the equipment, ETP may attain a favorable cost ratio when compared with conventional traffic paints. The higher initial costs for ETP are balanced by the reduction in marking operations.

At $0.17 to $0.18 per linear foot ($0.57 per linear meter), ETP would cost about 4.5 to 5 times as much as contract-installation of conventional traffic paint. If the material can be made to last six times as long traffic paints, the material will be cost-effective.

Table 12. Comparison of installed costs

Installed Cost	**Paint***	**Thermoplastic****	**Epoxy****
Per Linear Foot	*$0.04* to $0.06	*$0.40 to $0.60*	*$0.40 to $0.45*
Per Linear Meter	$0.13 to $0.20	$1.31 to $1.97	$1.31 to $1.48
Service Life (Years)	*0.25* to 1	*3 to 5*	1 to 2
Cost Per Linear Foot	*$0.04* to $0.24	*$0.08 to $0.20*	*$0.40 to $0.225*
Cost Per Linear Meter	$0.13 to $0.79	*$0.26* to $0.66	$1.31 to $0.74

* - Costs in Kansas for installation by KDOT workers
** - Costs in Kansas for contracted installation

Manufacturing and retrofitting costs will be negligible for large-scale use of ETP.

Potential For Future Use

Technology transfer is one of the problems with any new material or device designed to save money or increase safety on highways. It always is difficult to get highway agencies to change established practices, and the high initial investment in new equipment for alternative marking technologies further discourage their use. The following sections discuss the promise shown in the past by each material, and its prospects for the future.

Epoxy Paint

Though epoxy paints have been around since the early 1970s, to date they have not experienced large-scale use. Unfamiliarity with the application equipment and procedures may be a factor. Research suggests that the two-part epoxy marking system is a cost-effective alternative to alkyd paint, even in contract applications. Areas with harsh winter seasons particularly should consider using epoxy paint, because it is so resistant to abrasion from the usual snow and ice control activities.

Polyester

Experience with polyester materials is limited, and not much information about their use has been disseminated. The service lives demonstrated in the field studies may be unrealistic to achieve on a regular basis. More basic research is needed on the factors and delineation variables that most profoundly affect this marking. When this research is completed, more widespread use of the material may become feasible.

Epoxy Thermoplastic

In addition to its extremely short no-track time and its excellent performance on all pavement types. ETP has several other distinct advantages. It is a 100 percent solids formulation and is virtually smokeless at application temperatures. These properties are helpful when considering environmental impact of marking operations.

EPT has shown promise for large-scale implementation. Efforts to encourage increased use by State DOTs and other highway agencies are under way. A model ETP composition specification has been produced and work continues on retrofitting designs for existing marking equipment.